# NuMI Profile Monitors

Gianni Tassotto/Robert Webber

# Charge to Committee

- **assess whether** the **technical, resource and schedule aspects of instrumentation is sufficiently developed** to commission the NuMI beamline in January 2005.
- **Are specifications defined** and founded on a good technical basis?
- Do all sub-systems have a **clearly defined project manager and resource loaded schedule?** Are there **clearly defined milestones** for key tasks**?**
- **Are BD Instrumentation Dept resources sufficient** to complete NUMI instrumentation and have it completely checked out and operational on schedule for commissioning **while meeting other program instrumentation needs?**
- **Is a parallel design path for the beam profile monitor advisable?** Is there sufficient technical and resource **confidence** in 1) the "thin multi-wire" design or the "thin foil" design and 2) the "rotary insertion" design or the "bayonet insertion" design to **warrant an immediate decision?**

# Outline of this Presentation

- Requirements reference
- Geography
- Device itemization and provider
- Multi-wires for baseline plan
- Plan B presentation
- Technical considerations
- Cost and Schedule
- Concerns and Conclusions

- Note: Plan B presentation represents the technical understanding and estimates of Fermilab BD Instrumentation. It does not address impacts the plan change might have on UT costs, schedules or deliverables.

# Requirements References

- NUMI Technical Design Handbook – section 4.1.3, revision date 12/05/02
- Childress memo to email distribution received 10/2/03 describing "Proposed Plan"

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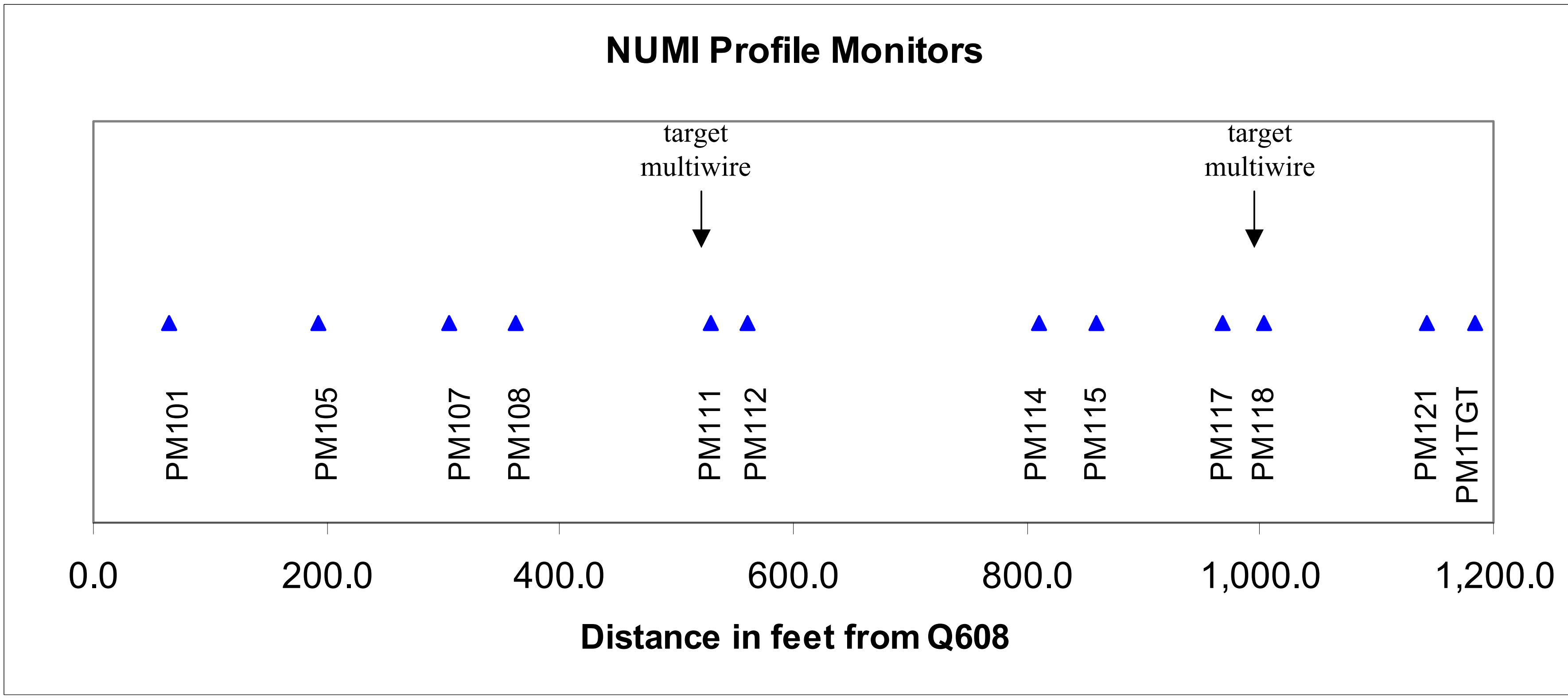
# Profile Monitor Layout




**12 devices over 1200 ft. beamline**

# Baseline Plan

| Name in Enclosure | Baseline Plan | Distance from Q608 in Feet |
|---|---|---|
| PM101 | UT 1mm SEM | 65.0 |
| PM105 | UT 1mm SEM | 192.4 |
| PM107 | UT 1mm SEM | 305.5 |
| PM108 | UT 1mm SEM | 362.1 |
| PM111 | FNAL 1mm x 3mil MW | 529.9 |
| PM112 | UT 1mm SEM | 559.9 |
| PM114 | UT 1mm SEM | 810.1 |
| PM115 | UT 1mm SEM | 859.0 |
| PM117 | UT 1mm SEM | 968.3 |
| PM118 | FNAL 1mm x 3mil MW | 1,003.8 |
| PM121 | UT 0.5mm SEM | 1,143.9 |
| PMTGT | UT 0.5mm SEM | 1,184.8 |

# Baseline Plan

- Fermilab provides:
  - 2 standard multiwires with 0.003” wires at 1mm pitch
  - Standard SWIC scanner readout electronics for both Fermilab and UT devices
  - Motion control electronics for both Fermilab and UT devices
  - Cabling, installation, and utilities support
  - Some support for UT devices
    - Survey/alignment fiducialization?
    - Vacuum testing?
    - ??

# "Standard" Profile Monitor

- Round vacuum can with 6" top flange.
- 4 or 6" beam tube vacuum quick disconnect flanges
- NOR-CAL 4 1/2" CF flange on bottom of can for ion pump
- Varian rotary feedthrough.
- 50 pin CeramTec electrical feedthrough for wire plane signals.
- HV feedthrough for bias foils.
- **Vacuum performance**: The chamber is tested for installation at $10^{-8}$ Torr using a 30 l/sec ion pump before installation in beamline.

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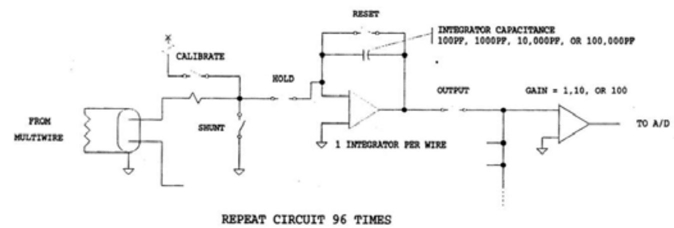
# "Standard" Wire Plane Assembly

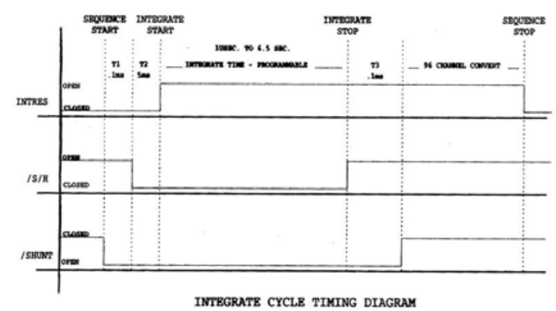
- Material: Ceramic frame.
- X, Y wire planes made using 0.003" wire soldered to printed pads on either side of ceramic frame.
- Wire: AuW 2% Re wire made by California Fine Wire.
- Wire pitch: choice of 0.5, 1 and 2 mm.
- Wire tension 80 g at winding.
- Kapton ribbon cables carry signals from wire planes to feedthroughs.
- No bias foils
  - KTeV tests show no effect on signal
  - CERN has evidence of better signal stability at high beam intensities with bias foils

# Standard Readout

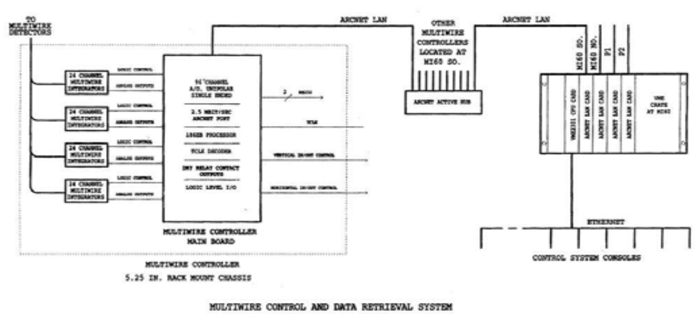
- FNAL made 96 channel integrator.
- Integration time from 5 μsec - 6.5 sec.
- Dynamic range: ≅ $E^{10}$ to >$10^{13}$ ppp
- 16 bit ADC.
- Noise ≅ 0.2% of full scale.
- Calibration feature.

## Integrate Cycle




## Controls



# Baseline Plan Fermilab Status

- Fermilab provided equipment:
  - Fermilab Multiwires (BD Instrumentation)
    - All parts on hand or in procurement
  - Readout Electronics (BD Controls)
    - 8/12 fabricated, 6/12 installed, 4/12 currently in fabrication
  - Motion Control for Fermilab Multiwires (BD Instrumentation)
    - Everything is on Gianni's shelf in wait
  - Motion Control for UT SEM Profile Monitors (BD Instrumentation)
    - Awaiting information
  - M&S expenses for 2 multiwires are already nearly 100% costed
- Fermilab provided support for UT SEMs
  - Preparing to install SEM in MiniBooNE beamline this shutdown
  - Anything else from Sacha's talk

# Fermilab Effort Remaining (Baseline)

- Gianni Tassotto, project manager
  - BD Instrumentation (management, assembly, install, UT device support) :
    - Gianni Tassotto - 40% through Sept ‘04
    - Engineering Dan Schoo - 25% through Sept ’04
    - Technician Rick Pierce - 25% through Sept ‘04.
  - PPD or BD Vacuum Support (vacuum certification of beamline devices)
    - 1+ day per device
  - Alignment Group Measurement and Fiducialization
    - Ed Dijak? – 1-2 days per device after assembly and ¼ day per device after installation in beamline
  - BD Mechanical Department
    - 2 technicians - 1 week during installation in summer ‘04
  - BD Controls (signal readout and motion control)
    - Al Franck/ Joe Gomilar – 1 month readout fabrication/installation
    - Al Legan – 1 month motion control electronics procure/assemble/install

# Plan B

| Name in Enclosure | Baseline Plan | Proposed Plan B | Distance from Q608 in Feet |
|---|---|---|---|
| PM101 | UT 1mm SEM | modified FNAL 1mm x 1mil MW | 65.0 |
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# NuMI Multiwire Specifications

- Allowable fractional beam loss < $10^{-5}$ per detector (2 planes).
- Insertable/Removable without exceeding allowable beam loss.
- Position & Stability : 50 μm.
- Vacuum: $10^{-8}$ Torr using a 30 l/sec ion pump.
- Standard Fermilab readout.
- Wire pitch: 1 mm x, y planes except 0.5 mm for two multiwires immediately upstream of target.
- Capability for bias foils.

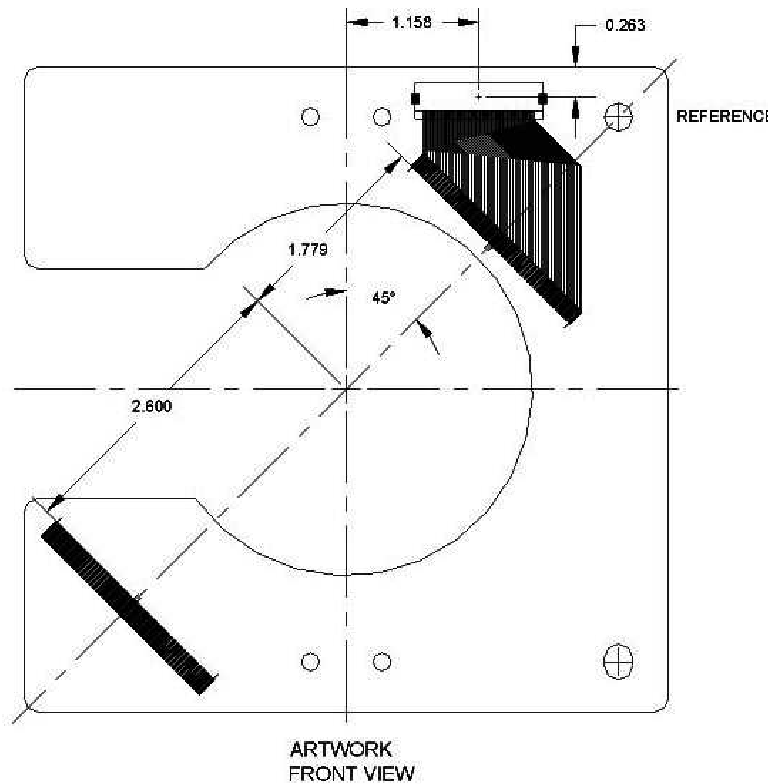
# To Support the Plan

- Reduce wire diameter from 0.003” to 0.001” to reduce beam loss
- Design open-sided wire frame to permit “live” insertion/retraction
- Add 5um thick bias foils with beam clearance hole
- Design stand to accommodate $45^0$ mounting required by open-sided frame with H/V wires
- Verify 50 um positioning repeatability
- Provide estimate of cost and manpower for modified plan

# Ceramic Wire Frame Modifications

- The drawing shows the open frame design to satisfy the NuMI insertion requirement.
- Plan to pre-stress frame before wires are attached.
- Open edge is at $45^0$ to wires
- Frame is mounted square (normal) in vacuum can, can is mounted at $45^0$ to present horizontal/vertical wires to beam.

- **Ceramic frame with pads at $45^0$.**



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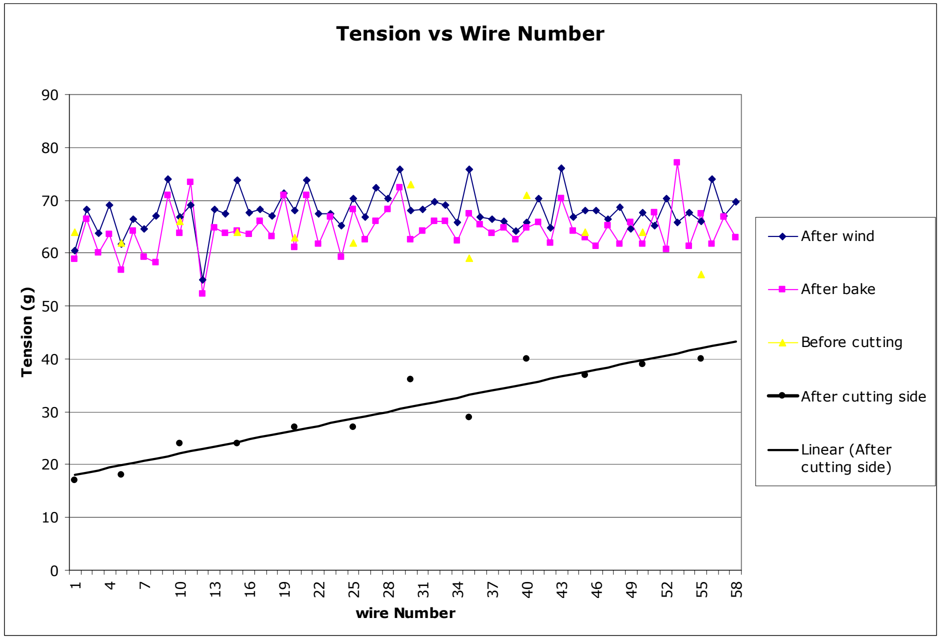
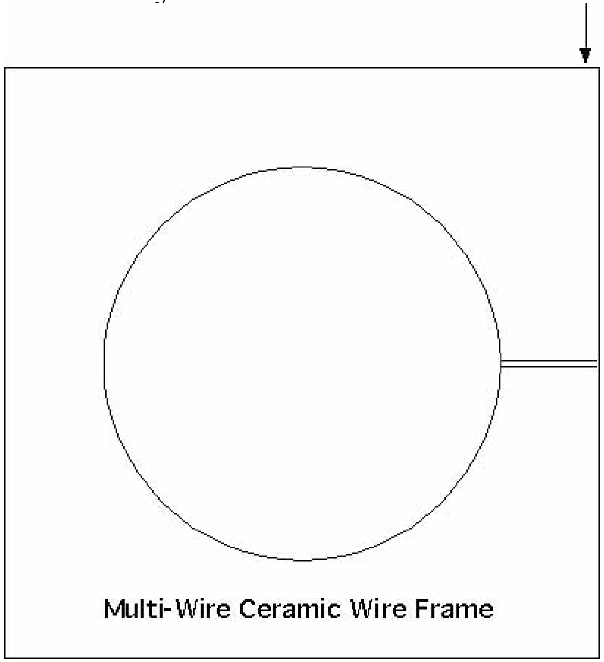
# Wire Tension Test for Open Frame Assembly

- **Wire tension before and after cutting side of existing ceramic board with wires already attached.**




- **Applied 14 lbs to one edge. Dial indicator showed no change at sensitivity better than 0.001"**



# Thermal Analysis

- Nikolai Mokhov, using MARS, has calculated peak instantaneous temperature rise for 0.003” Gold-Tungsten and Carbon wires for multiwires in the NuMI beamlines. Results here are for a 120 GeV beam at $3x10^{13}$ ppp.
- Maximum Delta_T (degrees C) in central (wire-1) and next three (wire-2, wire-3, wire-4) wires are presented below.

| Beam | Material | Beam Sigma (mm) | wire-1 | wire-2 | wire-3 | wire-4 |
|---|---|---|---|---|---|---|
| NuMI | W | 1 | 779.0 | 468.1 | 110.4 | 11.0 |
| | W | 2 | 211.7 | 181.8 | 26.5 | 67.1 |
| | C | 1 | 223.4 | 135.2 | 34.7 | 2.8 |
| | C | 2 | 72.1 | 57.8 | 40.4 | 21.7 |

- These calculations will be repeated for a 0.001” AuW wire. We have no experience using carbon wires in multiwires.
- For W, allowable temperature for 50 grams tension = $1000^0$ C. (maintain 15 Kpsi yeld strength).

# Insertion Repeatability

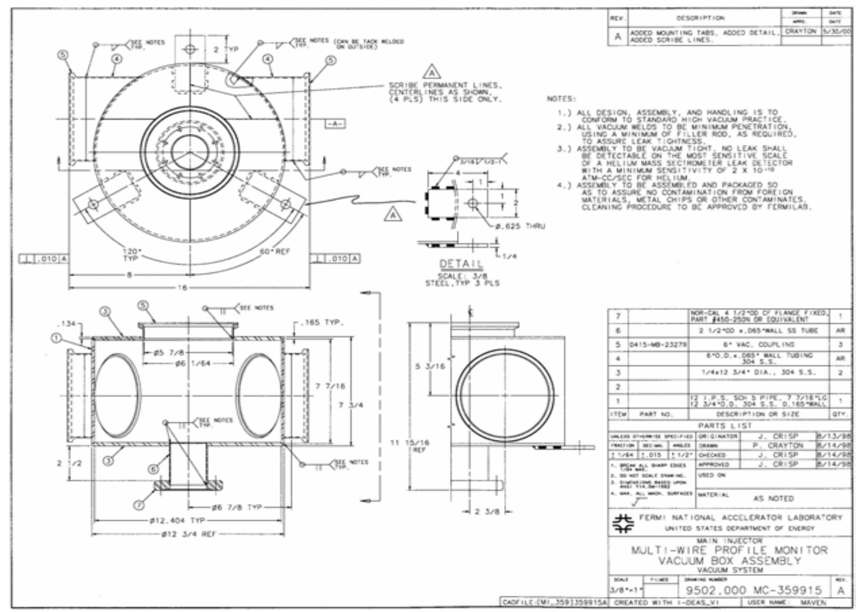
- The alignment group made several measurements of the IN position of all the MiniBooNE multiwires.
- The measurements were performed at the alignment building using a ceramic frame to support the wire plane assembly. The wire plane assembly was moved in/out 20 times per multiwire. Using 2 Bronson transit optical systems, the position of the central wire (transverse) and the position of the edge of the wire frame were found to be accurate to ±50 um.
- Need to verify similar performance for $45^0$ mounting.

# Chamber Deflection Measurement

## Chamber deflection due to vacuum loading on top of can:

- Under vacuum the 1/4” top plate was measured to deflect by 0.012”.
- J. Misek has calculated:
  - 0.250” plate - 0.015”
  - 0.375” plate - 0.004”
  - 0.500” plate - 0.002”

- No calculation has been made on side wall of vacuum chamber because it has only a secondary effect.
- The impact of the deflection is for fiducialization in the beamline.



# Near Term Effort

- New ceramic boards have been ordered. Expect to have a prototype wire plane assembly for testing by Dec. 1st 2003.
- Tension tests using 0.001” AuW wire, mechanical assembly and referencing should be completed by the end of December 2003.
- Modifications to the vacuum can to reduce vacuum distortion can commence at anytime; if a decision is made to do this.

# Delta Deliverables by Fermilab for Plan B

- Fermilab provided equipment:
  - Fermilab Modified Multiwires 5+spare (BD Instrumentation)
    - Need to complete development and modification design work
    - Need to procure/fabricate 6 modified multiwires (vacuum cans on hand)
    - Can drop 2 standard multiwires
  - For UT Profile monitors 5+spare (BD Instrumentation)
    - Need to provide UT with vacuum can and motor assemblies design data
  - Readout Electronics (BD Controls)
    - No different from Baseline Plan
  - Motion Control for Fermilab Multiwires and UT Profile Monitors (BD Instrumentation)
    - Need to procure parts and assemble additional 10 control units
  - Motion Control for UT Foil Devices (BD Controls)
    - 2 devices in Plan B, relative to 5 devices in Baseline
- Fermilab provided support for UT Profile Monitors and Foil Devices
    - Similar as for baseline plan except long-term maintenance of two UT devices

# Delta Fermilab Manpower Requirements

- BD Instrumentation (management, assembly, install, UT device support)
  - Gianni Tassotto - 40% -> 60% through Sept '04
  - Engineering Dan Schoo - 25% -> 50% through Sept '04
  - Technician Rick Pierce - 25% -> 50% through Sept '04.
- PPD or BD Vacuum Support (vacuum certification of beamline devices)
  - Similar to Baseline plan
- Alignment Group Measurement and Fiducialization
  - Similar to Baseline plan
- BD Mechanical Department
  - Similar to Baseline plan - 1 week during installation in summer '04
  - Additional 1 man month for design of 45° mounting stands
- BD Controls (signal readout and motion control)
  - Similar to Baseline plan

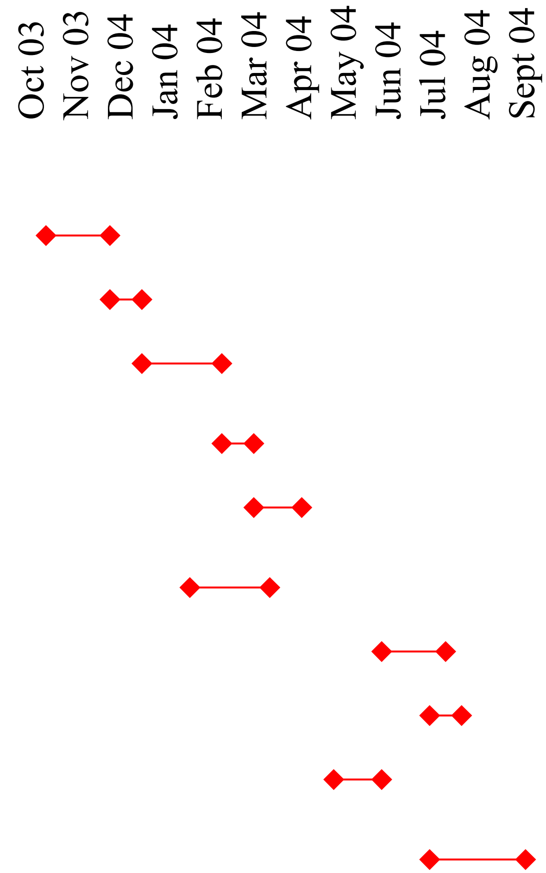
# Estimated Delta Plan B M&S Cost

| | | | | | |
|---|---|---|---|---|---|
| • Modification to vacuum can | $500 | x | 6 | $3000 | minus 6 UT cans |
| • Motor assemblies | $2000 | x | 6 | $12000 | minus 6 UT motors |
| • 6" top flange (with feedthroughs) | $1200 | x | 6 | $7200 | minus 6 UT cans |
| • Varian rotary feedthrough | $650 | x | 6 | $3900 | minus 6 UT drives |
| • Wire frame & support shaft | $2500 | x | 6 | $21000 | minus 6 UT frames |
| • Wire plane assembly & wiring | $350 | x | 6 | $2100 | |
| • | Total: | | | $49,200 | minus $UT ??? costs |

- UT absorbs cost of producing Fermilab cans/drives for their 6 units
- Costs remain for UT development of linear drive foil devices, for incorporating SEM foils into standard Fermilab can, and ???

# Time estimate

- Procure & assemble prototype 1 mil wire plane
- Test 1 mil wire plane assembly
- Assemble and test remaining wire planes
- Reference wire planes
- Bake complete assemblies and vacuum certify
- Design and build stands
- Install in beamline
- Survey
- Install electronics
- Systems tests



# Plan B Risks and Other Costs

- Technical risk – probably few (*editorial: except UT may have very tough time designing SEM profile device compatible with constraints of Fermilab can*)
- Schedule risk – probably small, but only if decision to proceed is prompt
- Other cost – same manpower is expected to support accelerator beamline instrumentation and to be available for commissioning and operation of SY120; that level of support will be reduced
- Operational cost - increased beam losses relative to baseline UT SEM profile monitor

# Conclusion and Caveat

- R&D of modified designs could be completed by end of January 2004.
- Production of modified Fermilab multiwires for NuMI could commence in January 2004 and be ready for installation in the summer 2004.
- This plan should be comfortably doable by identified Fermilab resources, but not without some cost in terms of dollars and re-direction of manpower. (We are not hoping to do this for lack of other work!)
- "Notice to proceed" is required by December 1, 2003 if schedule is to be met.

# My Observations on NuMI Instrumentation

- NuMI instrumentation effort overall would benefit by identification of full-time, 100% duty factor, "instrumentation czar" who could organize and manage efforts with eye to project requirements, engineering considerations, schedule, and manpower availability
- BD Instrumentation does not have person available to do this
- Requirements for instrumentation systems to "qualify" MI beam as acceptable for extraction to NuMI are not defined! The ability to qualify the beam has been identified as very important.
- Detailed specifications of signals or data to be provided to beam permit system by instrumentation systems are not documented.
- Instrumentation Department has not been involved in definition of specifications or identification of resources for applications software; are these activities happening elsewhere?